UNIVERSITI PUTRA MALAYSIA

EMI SUPPRESSION CHARACTERISTICS OF PURE AND IMPURE Ni-Zn FERRITIES AND Mg-Zn FERRITIES

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By

EWE LAY SHENG

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Institution of Advance Material Universiti Putra Malaysia

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of requirement for the degree of Master of Science

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November 2001

Chairman : Assoc. Prof. Dr. Mansor Hashim
Faculty : Institut Teknologi Maju

Electromagnetic Interference (EMI) is a wave pollution, which interrupts the functioning of electronic circuits. Therefore, EMI wave absorbing materials are needed to suppress the wave pollution. One of the best solutions to overcome this problem is by using ferrites as EMI suppressors. This work is hoped to give a better understanding on how the purity of constituent oxides affects the suppression capability of ferrites. Moreover, it is also hoped to contribute in understanding how a good EMI suppressor can be made. A total of 12 toroidal samples with the composition of $Ni_xZn_{1-x}Fe_2O_4$ and another 12 toroidal samples with the composition $Mg_xZn_{1-x}Fe_2O_4$ were prepared via the conventional ceramic processing method, where x = 0.1, 0.15, 0.2, 0.25, 0.3, 0.35. These samples were prepared to be ferrites with purities ~99.99% and $\leq$99.1% which denoted pure and impure ferrites respectively. Subsequently, these samples were sintered in air at 1300°C. The measured parameters to study the magnetic properties were density, permeability, relative loss factor, impedance, resistivity, microstructure and XRD analysis. It was found that the overall magnetic properties for pure Ni-Zn Ferrites and Mg-Zn Ferrites were only slightly better than those of impure Ni-Zn

ferrites and Mg-Zn Ferrites; the parameter values did not differ very much. Therefore, it is more economic if the impure materials are used for ferrite production instead of pure materials, which are more expensive.

Abstak tesis yang dikemukakan kepade Senat Universiti Putra Malaysia bagi memenuhi keperluan ijazah Master Sains

CIRI-CIRI PENUMPASAN EMI FERIT Ni-Zn DAN Mg-Zn TULEN DAN KURANG TULEN

Oleh

EWE LAY SHENG

November 2001

Pengerusi :Prof. Madya Dr. Mansor Hashim
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Inteferens electromagnet (EMI) adalah satu pencemaran gelombang yang menganggu pengoperasian litar-litar elektronik. Oleh sebab itu, bahan penyerap gelombang EMI diperlukan untuk menumpaskan pencemaran ini. Salah satu cara penyelesaian untuk mengatasi masalah ini ialah dengan menggunakan ferit sebagai penumpas EMI. Projek ini diharapkan akan memberi pemahaman yang lebih baik bagaimana ketulenan oxida yang digunakan mempengaruhi keupayaan penumpasan ferit. Tambahan pula, ia juga diharapkan dapat menyumbang kepada pemahaman mengenai bagaimana suatu penumpas EMI yang baik dapat dihasilkan. Sejumlah 12 sampel toroid dengan komposisi $Ni_xZn_{1-x}Fe_2O_4$ dan juga 12 sampel toroid dengan komposisi $Mg_xZn_{1-x}Fe_2O_4$ telah disediakan dengan kaedah lazim pemprosesan seramik, di mana x = 0.1, 0.15, 0.2, 0.25, 0.3, 0.35. Sampel-sampel ini telah disediakan sebagai bahan ferit yang mempunyai ketulenan ~99.99% dan ≥99.1% masing-masing dan ditandakan sebagai ferit tulen dan tidak tulen. Seterusnya, sampel-sampel ini

disinterkan dalam udara pada suhu 1300°C. Parameter yang diukur untuk mengkaji sifat magnet adalah ketumpatan, ketelapan, factor kehilangan relatif, impedans, kerintangan, analisis mikrostruktur dan XRD. Didapati bahawa secara keseluruhannya, sifat-sifat magnet bagi Ni-Zn Ferit and Mg-Zn Ferit yang tulen adalah hanya sedikit lebih baik daripada sifat-sifat maget bagi Ni-Zn Ferit and Mg-Zn Ferit yang tidak tulen. Nilai yang diukur mempunyai perbezaan yang tidak banyak. Oleh itu, adalah lebih ekonomik jika bahan yang kurang tulen digunakan untuk menghasilkan penumpas jika dibandingkan dengan bahan tulen, yang lebih mahal.

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Most importantly, I thank my husband for his rare kind of support and love.

I certify that an Examination Committee met on the 10th of November 2001 to conduct the final examination of Ewe Lay Sheng on her Master of Science thesis entitled "EMI Suppression Characteristics of Pure and Impure Ni-Zn Ferrites and Mg-Zn Ferrites" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows;

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Date: 10 JAN 2002

DECLARATION

I hereby declared that the thesis is based on my original work except for quotations and citations, which have been duly acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

EWE LAY SHENG

Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

EMI	electromagnetic interference
H	applied field
μ_B	Bohr magneton
H_c	coercive force
A	cross sectional area
T_c	Curie temperature
ρ*	density
f	frequency
γ	gyromagnetic ration
μ"	imaginary part of permeability or magnetic loss parameter
B	induction
L	inductance
μ_I	initial permeability
μ_B	Bohr magneton
D_i	inner diameter
σ	internal stress
l	length
$\tan\delta$	loss tangent
N	number of wire turns
D_o	outer diameter
μ_o	permeability of free space

PVA	polyvinyl alcohol
Q	quality factor
μ'	real part of permeability
RLF	relative loss factor
B_r	remanent induction
R	resistance
ρ	resistivity
B_s	saturated induction
M_s	saturation magnetization
T	temperature
Ω	Ohm
XRD	x-ray diffraction
W	weight
K	anisotropy constant
t	thickness

CHAPTER I

GENERAL INTRODUCTION

Oxide ceramics that exhibit ferrimagnetic behaviour play an important role in the electronics industry and are commonly known as ferrites. Today's technology of high frequency recording, power supplies, telecommunications, televisions and entertainment electronics would have been very different were it not for many useful properties of ferrites.

Ferrites are mixed metal oxides containing iron oxide as their main component. There are three classes of commercial ferrites, each one having a specific crystal structure. The first type is soft ferrites with cubic spinel structure such as NiZn-ferrites, MnZn-ferrites and MgMnZn- ferrites. The second type is soft ferrites with the garnet structure such as microwave ferrites and yttrium iron garnets. The third one is hard ferrites with the magnetoplumbite (hexagonal) structure such as Ba and Sr hexaferrites.

Like ferromagnetic materials, ferrimagnetic ceramics exhibit spontaneous magnetization in the absence of an external field, consist of self-saturated domains, and show the characteristic hysteresis behaviour (Cullity, 1972;Smit and Wijn, 1959;Heck, 1974). The major difference between these classes of materials (one primarily metals and the other ceramics) is that the resistivity of ferrites, depending on composition, is at least six to twelve orders of magnitude higher than that of ferromagnetic materials like permalloys and silicon irons. This has given ferrites a distinct advantage as magnetic materials of choice in high frequency applications, although their saturation magnetization is approximately one fifth to one eight that of silicon irons (Table 1.1). In addition, the crystal structures of ferrites are quite different depending on variations in their chemical compositions, giving the technologist access to a wide range of properties. Ceramic processing techniques allow the economic fabrication of devices in various shapes and sizes.

Table 1.1: Saturation flux density, resistivity, for several magnetic materials

Material	Flux density	Resistivity
Iron (100% Fe)	2.158	9.6×10^{-6}
Silicon-Iron (4% Si)	2	60×10^{-6}
Cobalt (99.95 % Co)	1.9	6.3×10^{-6}
Nickel (99.6 %)	0.608	8.7×10^{-6}
$FeO.Fe_2O_3$	0.6	4×10^{-6}
$MnO.Fe_2O_3$	0.52	10^4
$NiO.Fe_2O_3$	0.35	8×10^5
$CuO.Fe_2O_3$	0.17	10^5
$MgO.Fe_2O_3$	0.14	10^7
MnZn Ferrite	0.4-0.63	10^2-10^3
NiZn Ferrite	0.3-0.4	10^6
MgMn Ferrite	0.06-0.22	10^4-10^6
MgZn Ferrite	0.24-0.27	10^7-10^8
$BaO.6Fe_2O_3$	0.41	10^4-10^5
$5Fe_2O_3.3Y_2O_3$ (YIG)	0.17	10^{10}-10^{12}

Data from various sources including Heck (1974), Landolt-Bornstein (1970). The high value of flux density for MnZn ferrite is quoted from Kugimiya and Hirota (1989)

Depending on their coercivity (H_c), ferrites are said to be either soft if H_c ~1,000 A/m^{-1} or hard if H_c >10,000 A/m^{-1}. Soft ferrites may be subdivided further into two categories, one suitable for nonmicrowave applications (frequency << 100 MHz), and the other suitable for microwave applications (frequency >> 100 MHz).

This work focused primarily on soft ferrites used in EMI suppressor typically operating in the frequency range of 0.1 MHz to 250 MHz. A few basic concepts necessary to understand the behaviour of ferrimagnetic materials are described here.

Basic concepts

The magnetic properties of solids have their origin in the two types of electron motion, orbital and spin. Each has a magnetic moment associated with it. The fundamental quality, the *Bohr magneton* μ_B, is a measure of the magnetic moment caused by the spin of the electron, and is equal to 1.1645×10^{-29} Vsm (Cullity, 1972).

The magnetic moment associated with orbital and spin motion is a vector quantity, parallel to the axis of spin and normal to the plane of orbit, respectively. The net magnetic moment of the atom, therefore, is the vector sum of all its electronic moments. In most magnetic materials containing elements of the first group of transition metals the resultant orbital moment of electrons is much smaller than the spin moment. A comparison between the calculated and experimental values of the net magnetic moments for several divalent and trivalent metal ions is shown in Table 1.2.

Table 1.2: Effective Bohr magneton numbers for mostly divalent and trivalent ions of the iron group

Ion	Configuration	Calculated	Experimental
Ti^{3+}, V^{4+}	$3d^1$	1.73	1.8
V^{3+}	$3d^2$	2.83	2.8
Cr^{3+}, V^{2+}	$3d^3$	3.87	3.8
Mn^{3+}, Cr^{2+}	$3d^4$	4.9	4.9
Fe^{3+}, Mn^{2+}	$3d^5$	5.92	5.9
Fe^{2+}	$3d^6$	4.9	5.4
Co^{2+}	$3d^7$	3.8	4.8
Ni^{2+}	$3d^8$	2.83	2.8

Note: Values calculated as if the orbital moments were not there, Kittel (1969).

Ferrimagnetism

In metals such as iron, nickel, and cobalt (transition metals) having unfilled subvalence shells, the magnetic moments of the inner shell (the d shell) electrons remain uncompensated. This results in each atom acting as a small magnet. In addition, within each crystal the atoms are sufficiently close and the magnetic moments of individual atoms are sufficiently strong. This leads to strong positive quantum-mechanical exchange interaction and long range ordering of magnetic moments, which manifests itself as ferromagnetism. There are three conditions that must be met simultaneously before a substance shows ferromagnetic behavior (Heck, 1974):

1) There must be an unfilled electron shell within the atom.
2) There must be uncompensated electronics spins in this unfilled inner shell.
3) The ions of the atoms must form a crystal lattice having a lattice constant at least three times the radius of the unfilled electron shell.

If the adjacent moments are aligned antiparallel (Figure 1.1) as a result of strong negative interaction, and only one type of magnetic moment is present, the neighboring atomic moments cancel each other resulting in net zero magnetization. The material is

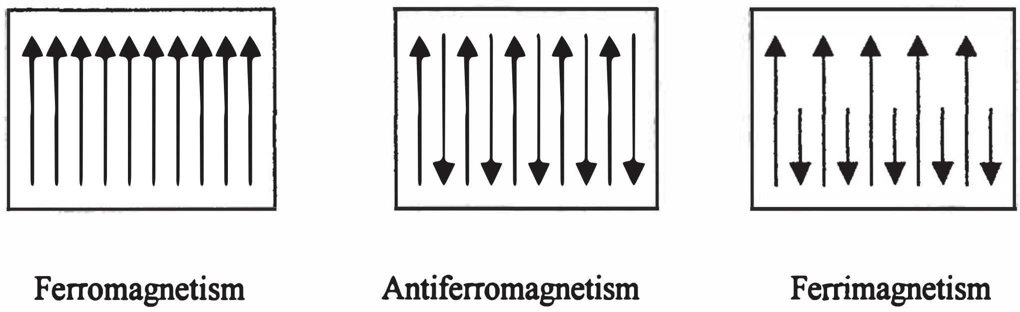

Figure 1.1: Schematic representation of magnetic moments

then said to exhibit antiferromagnetism. This situation can be interpreted as the result of simultaneous existence of two sublattices. A sublattice is a collection of all of the magnetic sites in a crystal with identical behavior, with all moments parallel to one another and pointing in the same direction, which are spontaneously magnetized and have the same intensity. Typical examples of antiferromagnetic materials are the metals Cr and α-Mn.

Sublattices (two or more) can also have spontaneous magnetizations in opposite directions but with different intensities. For instance, when a material contains magnetic ions of different species and magnetic moments, or of the same species occupying crystallographically inequivalent sites, the resultant moments of the sublattices lie parallel or antiparalllel to one another and the dominant exchange interaction is mediated by the neighboring non-magnetic ions. Such materials have a spontaneous magnetization, which is weaker than in materials whose magnetic